US008643805B2

(12) United States Patent
Nagato et al.

(10) Patent No.: **US 8,643,805 B2**
(45) Date of Patent: **Feb. 4, 2014**

(54) **BACKLIGHT AND LIQUID CRYSTAL DISPLAY DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/916,248**

(22) Filed: **Jun. 12, 2013**

(65) **Prior Publication Data**

US 2013/0271698 A1 Oct. 17, 2013

Related U.S. Application Data

(62) Division of application No. 13/040,902, filed on Mar. 4, 2011, now abandoned.

(30) **Foreign Application Priority Data**

Aug. 11, 2010 (JP) 2010-180590

(51) **Int. Cl.**
G02F 1/1335 (2006.01)

(52) **U.S. Cl.**
USPC **349/62**; 349/106; 362/97.2

(58) **Field of Classification Search**
None
See application file for complete search history.

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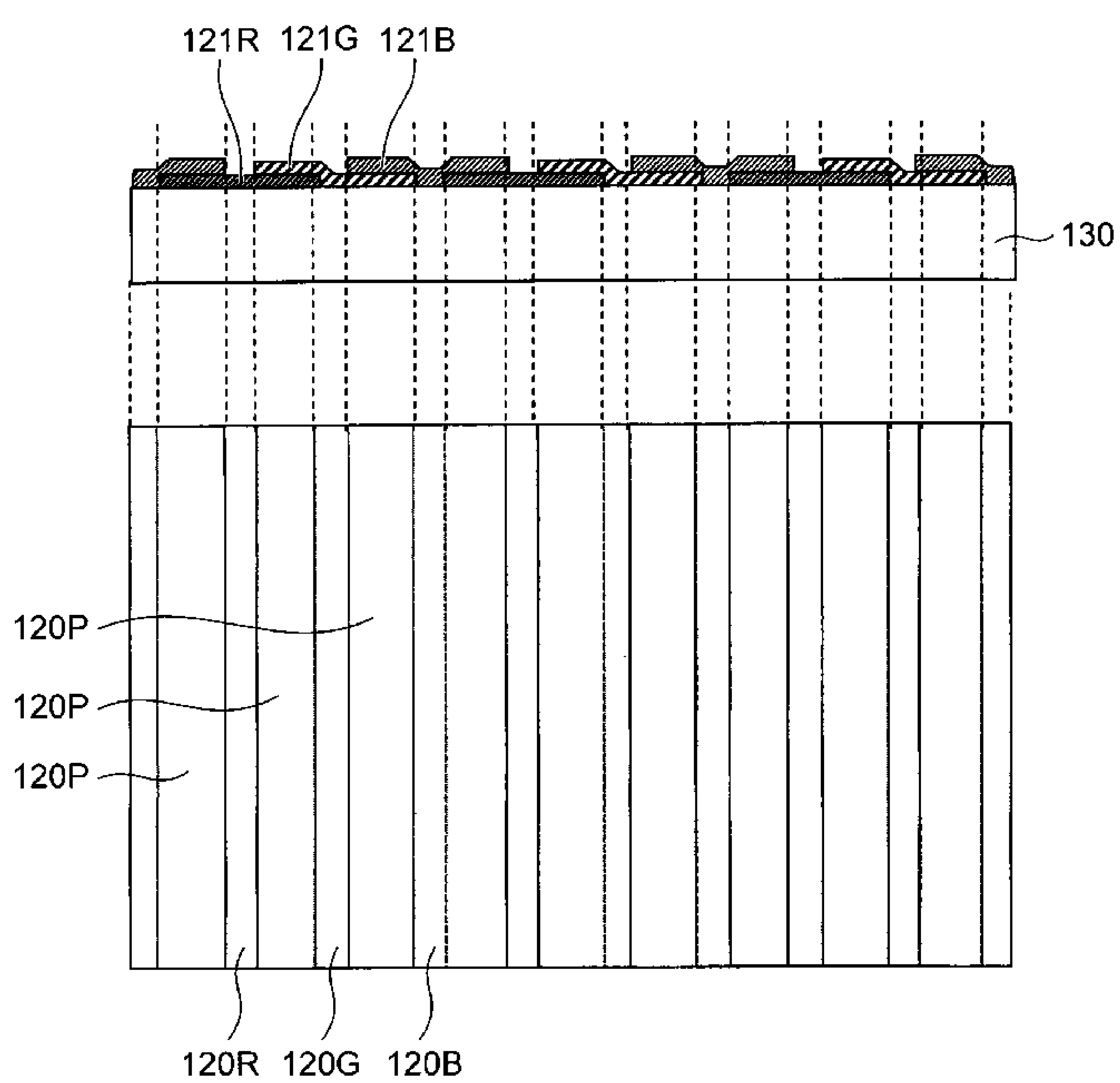
Primary Examiner — Richard Kim
(74) *Attorney, Agent, or Firm* — Oblon, Spivak, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

A backlight includes a case having plural apertures in a main face thereof and a light source disposed in the case. A total area of the plural apertures is not less than 8% and not more than 15% of an area of the main face.

2 Claims, 13 Drawing Sheets



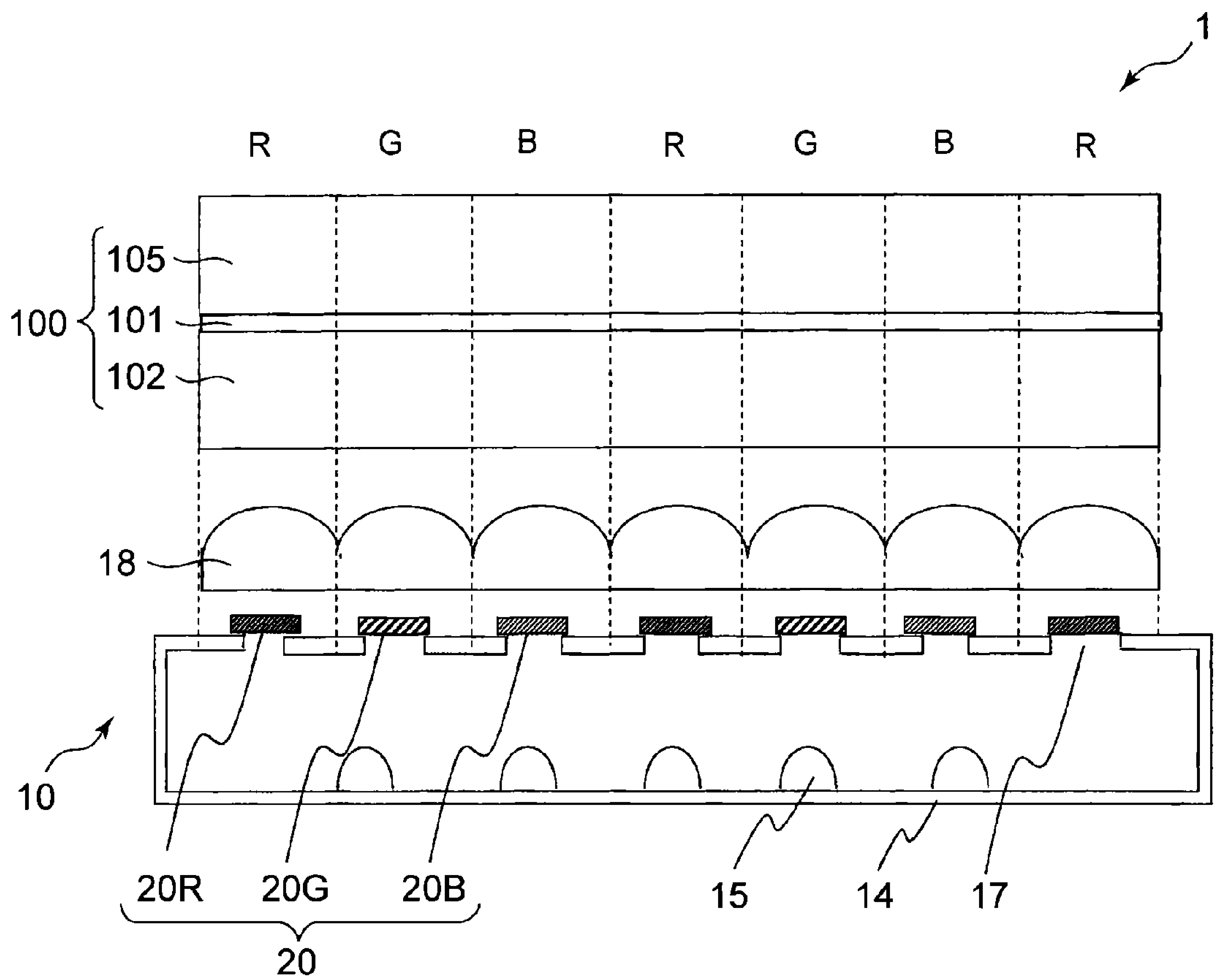


FIG. 1

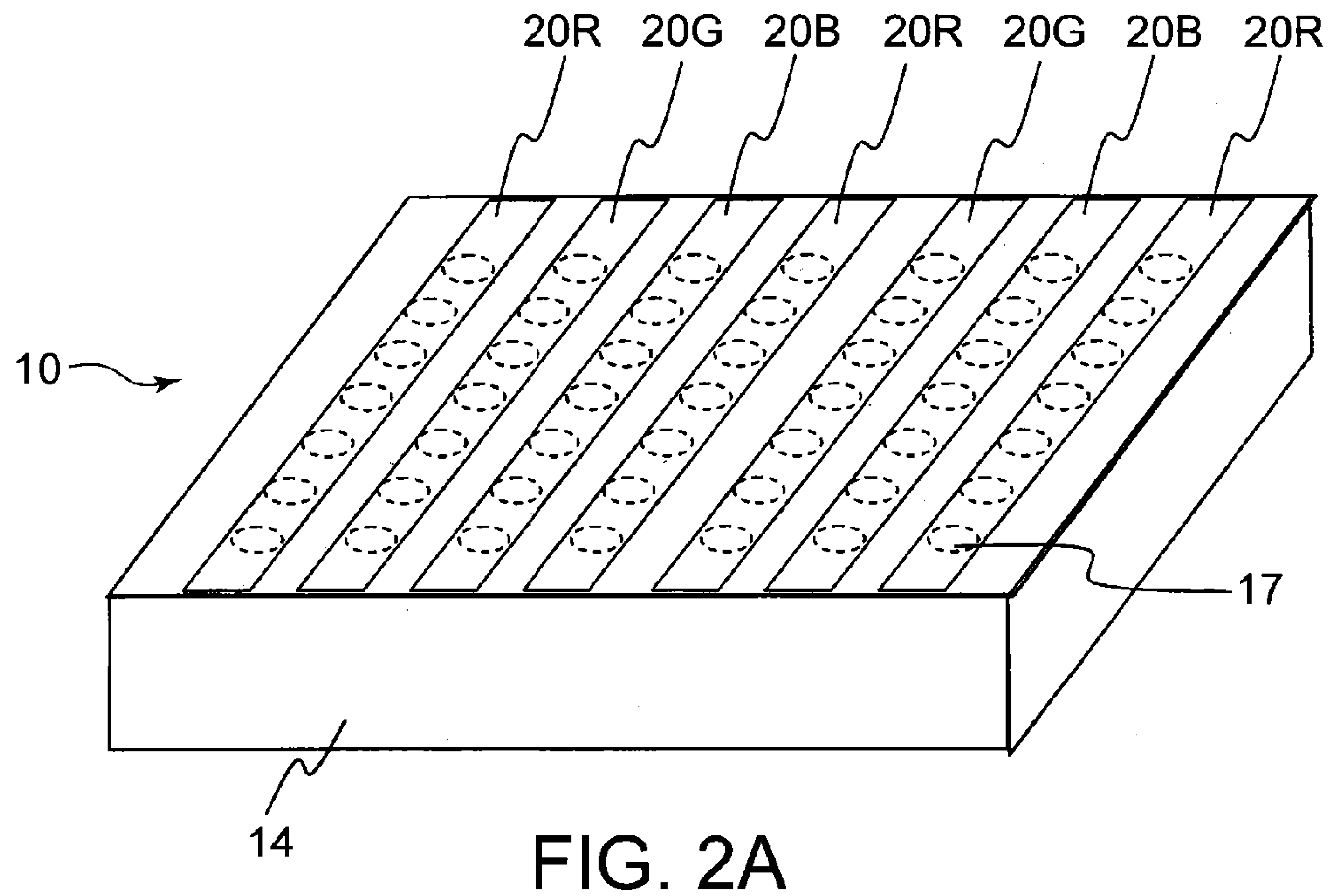

20R
20G
20B
20R
20G
20B
20R
10
17
14

FIG. 2A

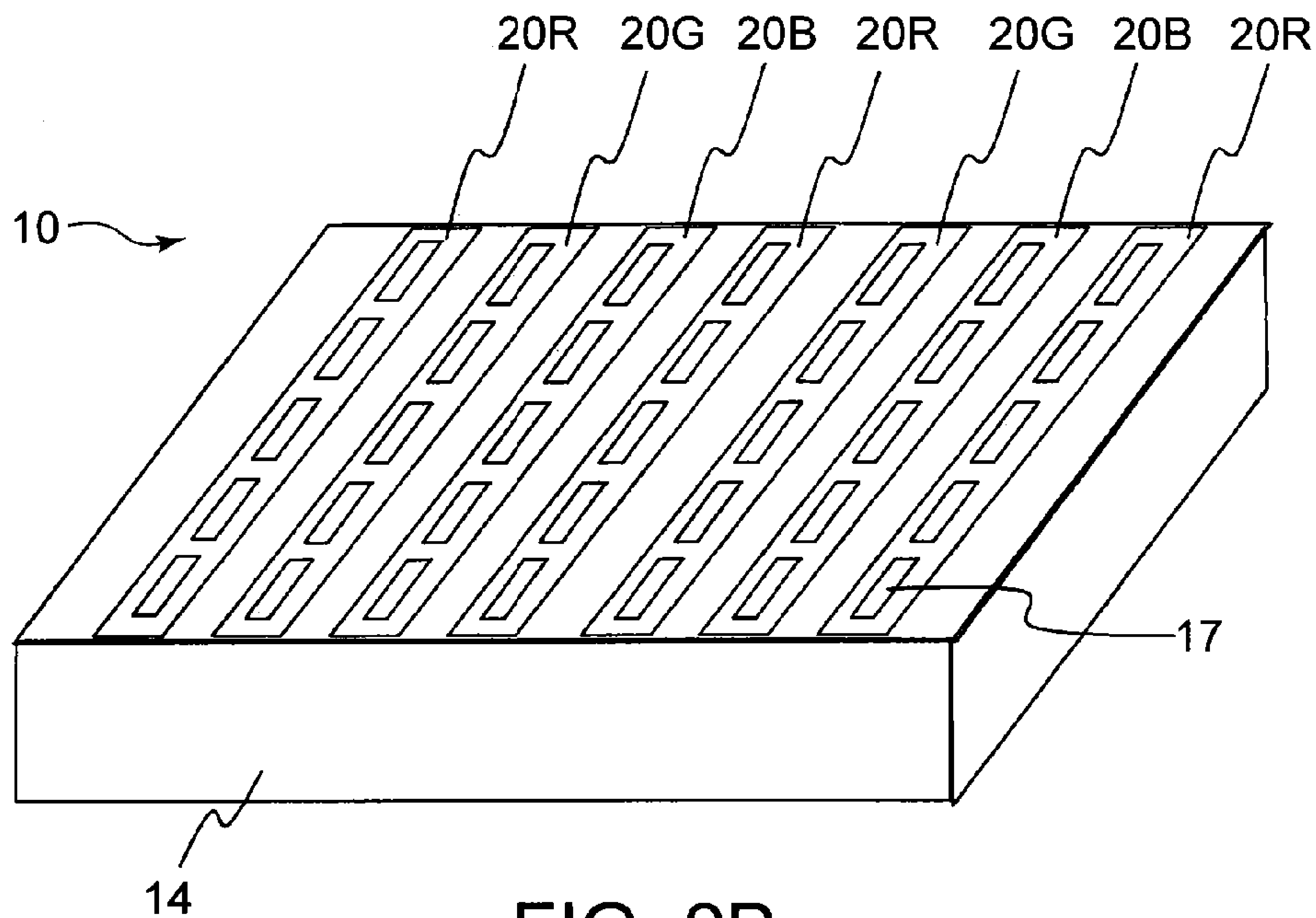

20R
20G
20B
20R
20G
20B
20R
10
17
14

FIG. 2B

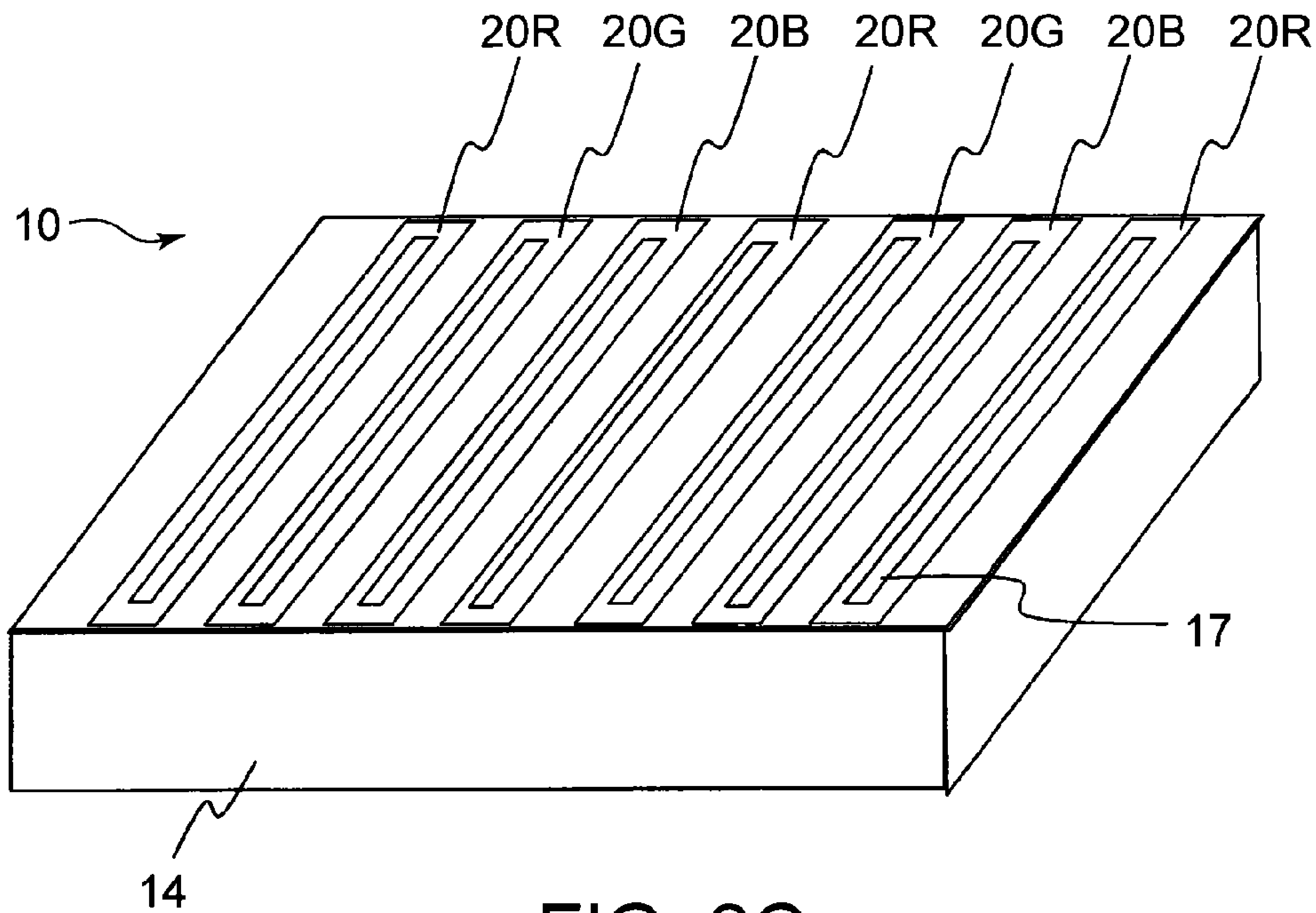


FIG. 2C

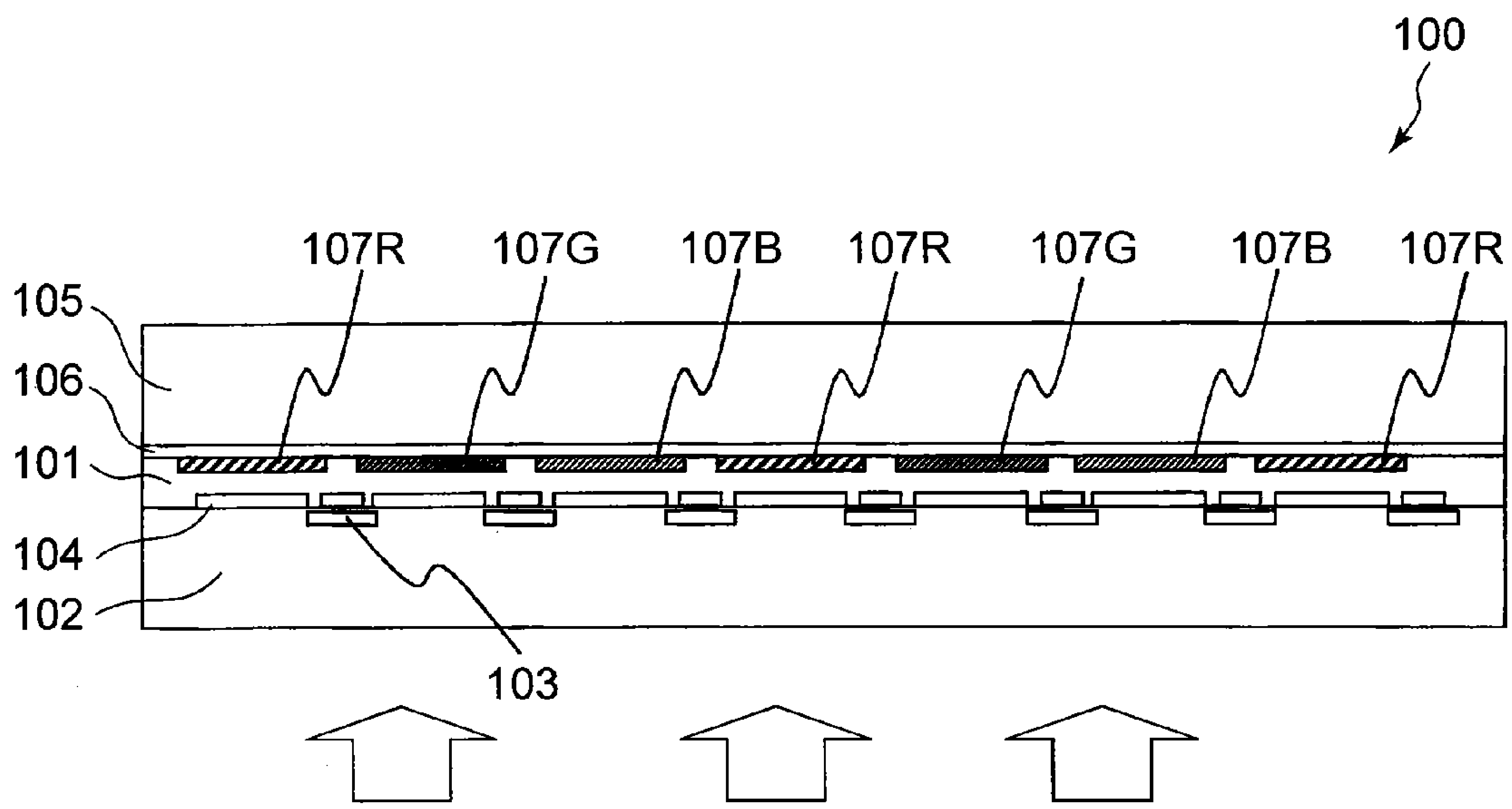


FIG. 3

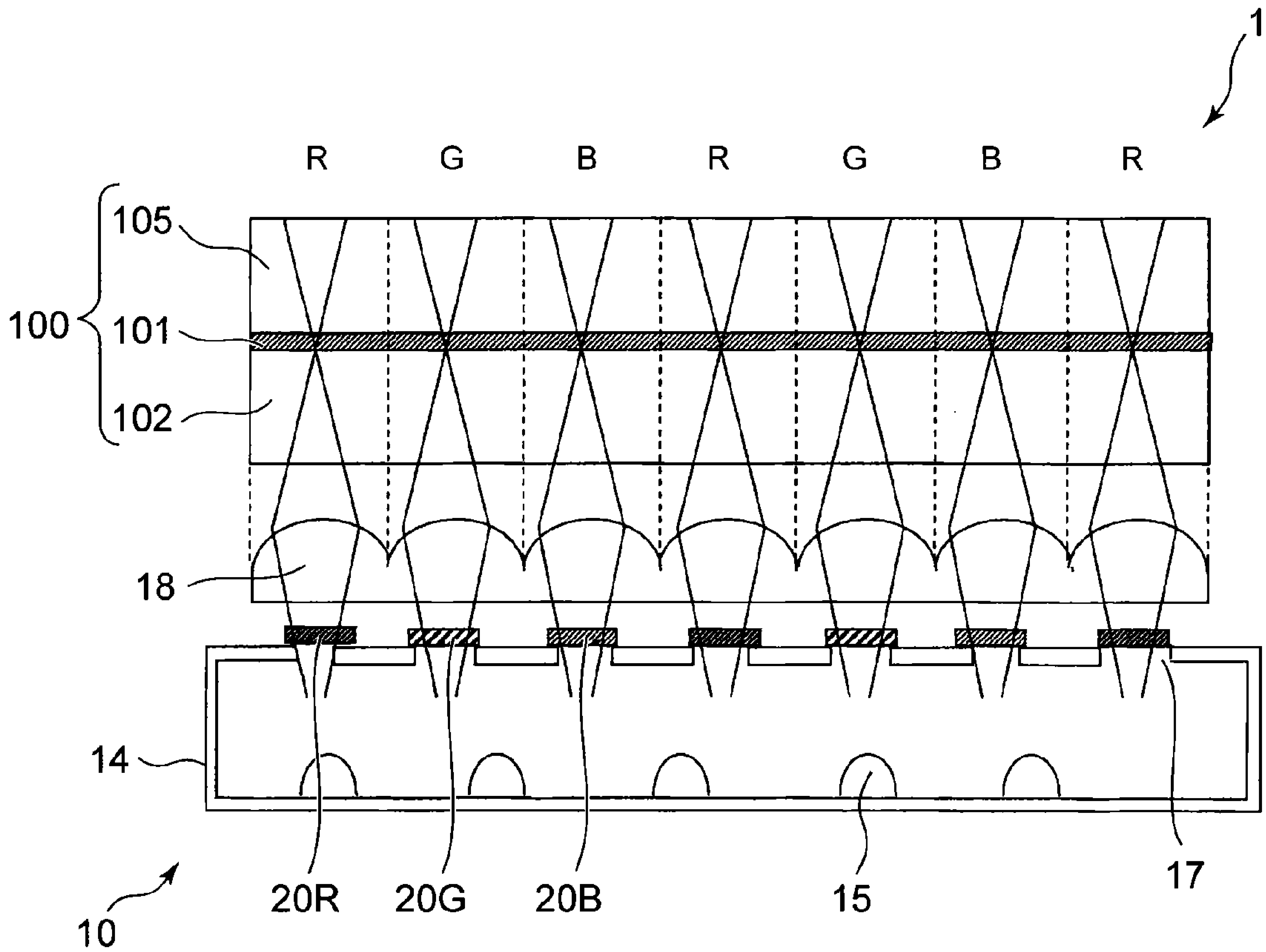
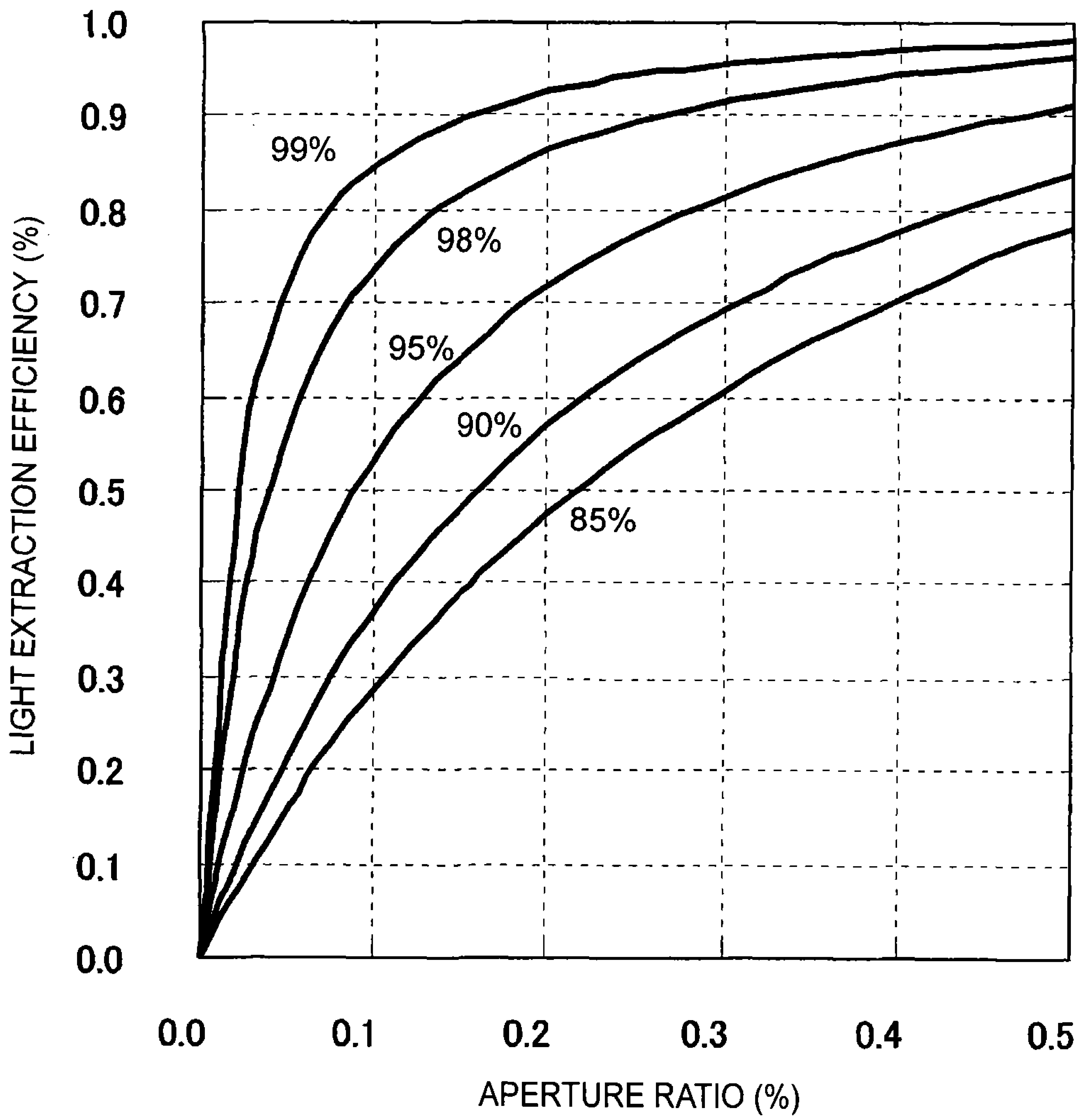


FIG. 4



1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
LIGHT EXTRACTION EFFICIENCY (%)
99%
98%
95%
90%
85%
0.0
0.1
0.2
0.3
0.4
0.5
APERTURE RATIO (%)

FIG. 5

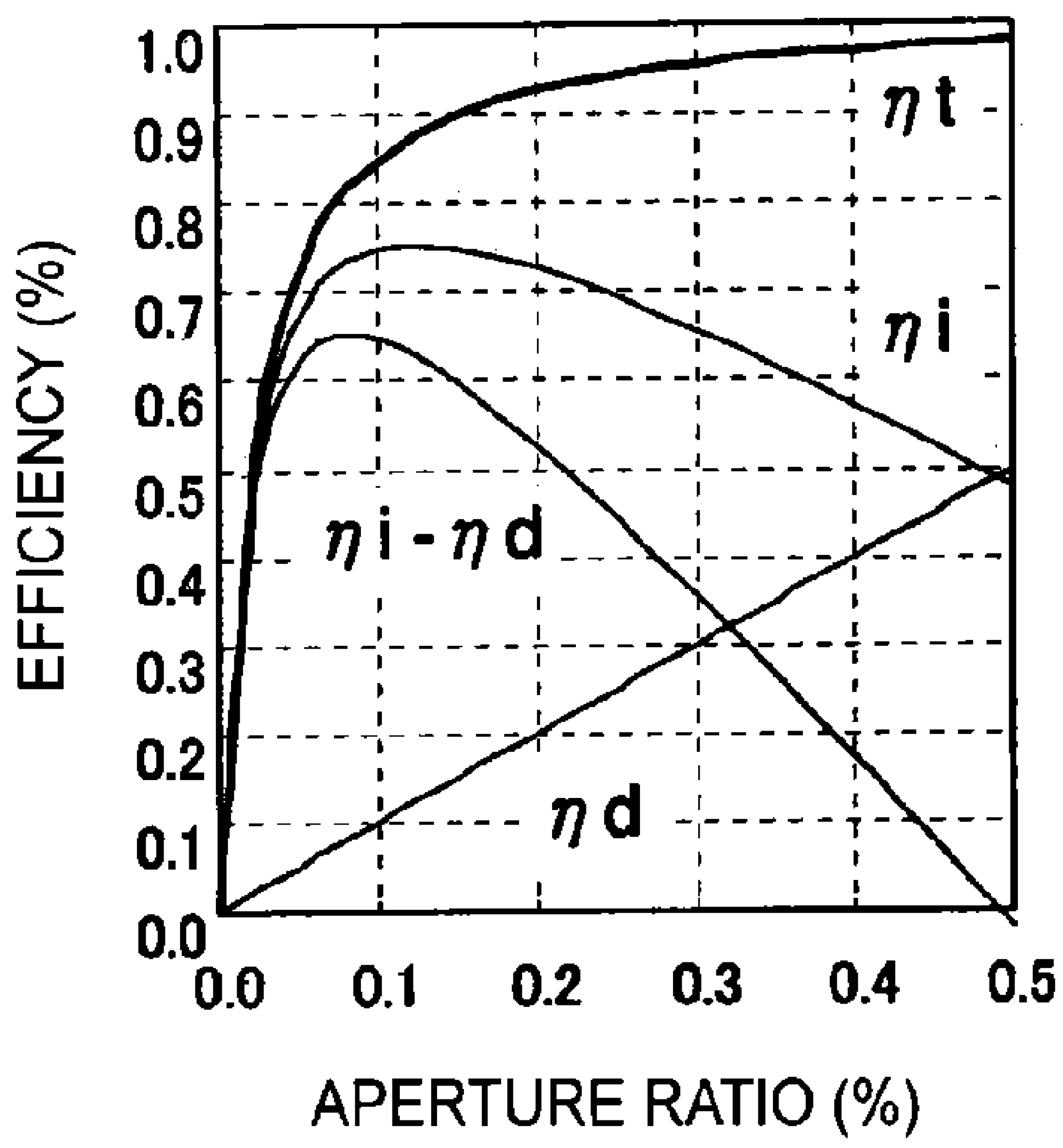


FIG. 6A

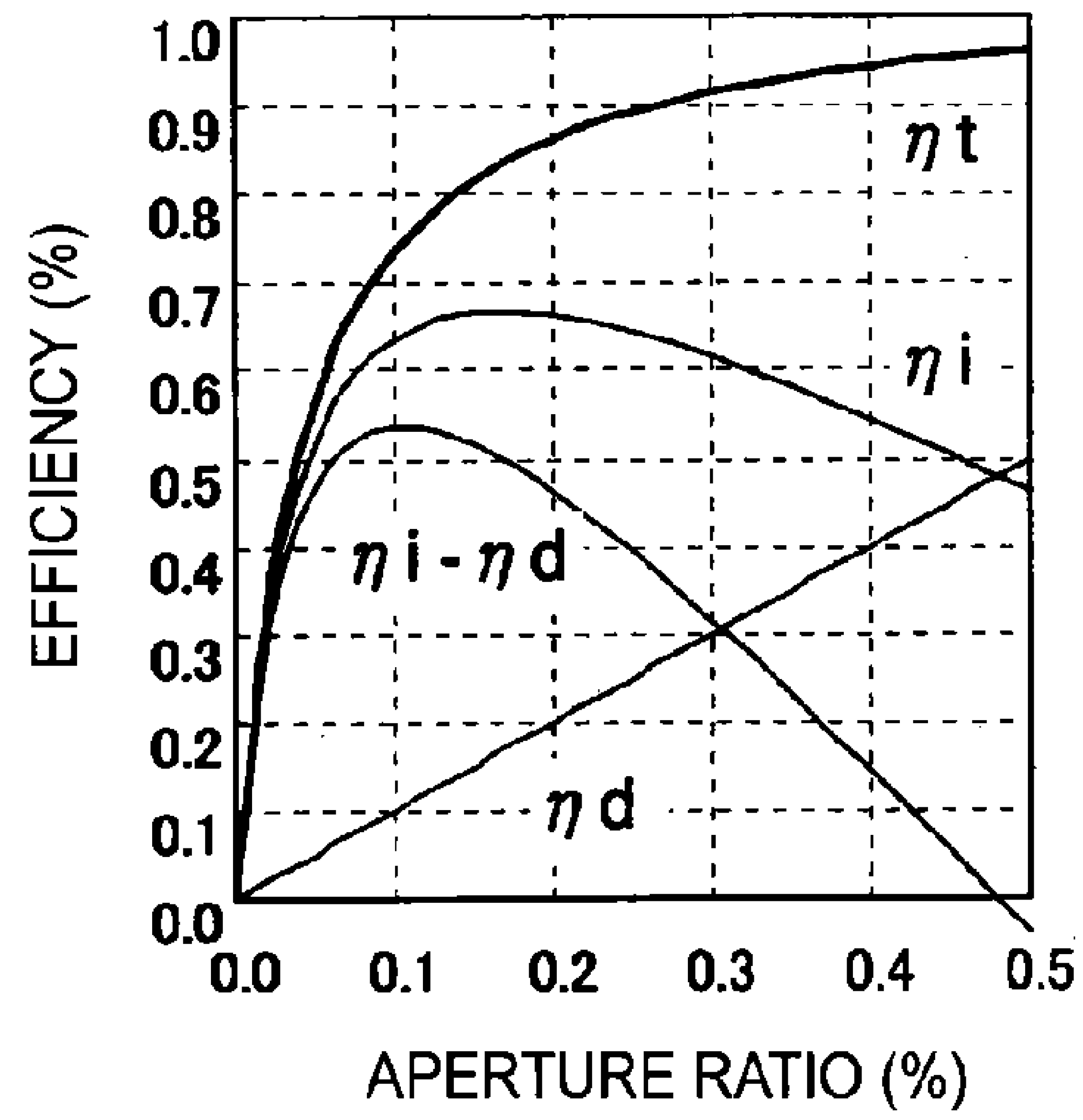


FIG. 6B

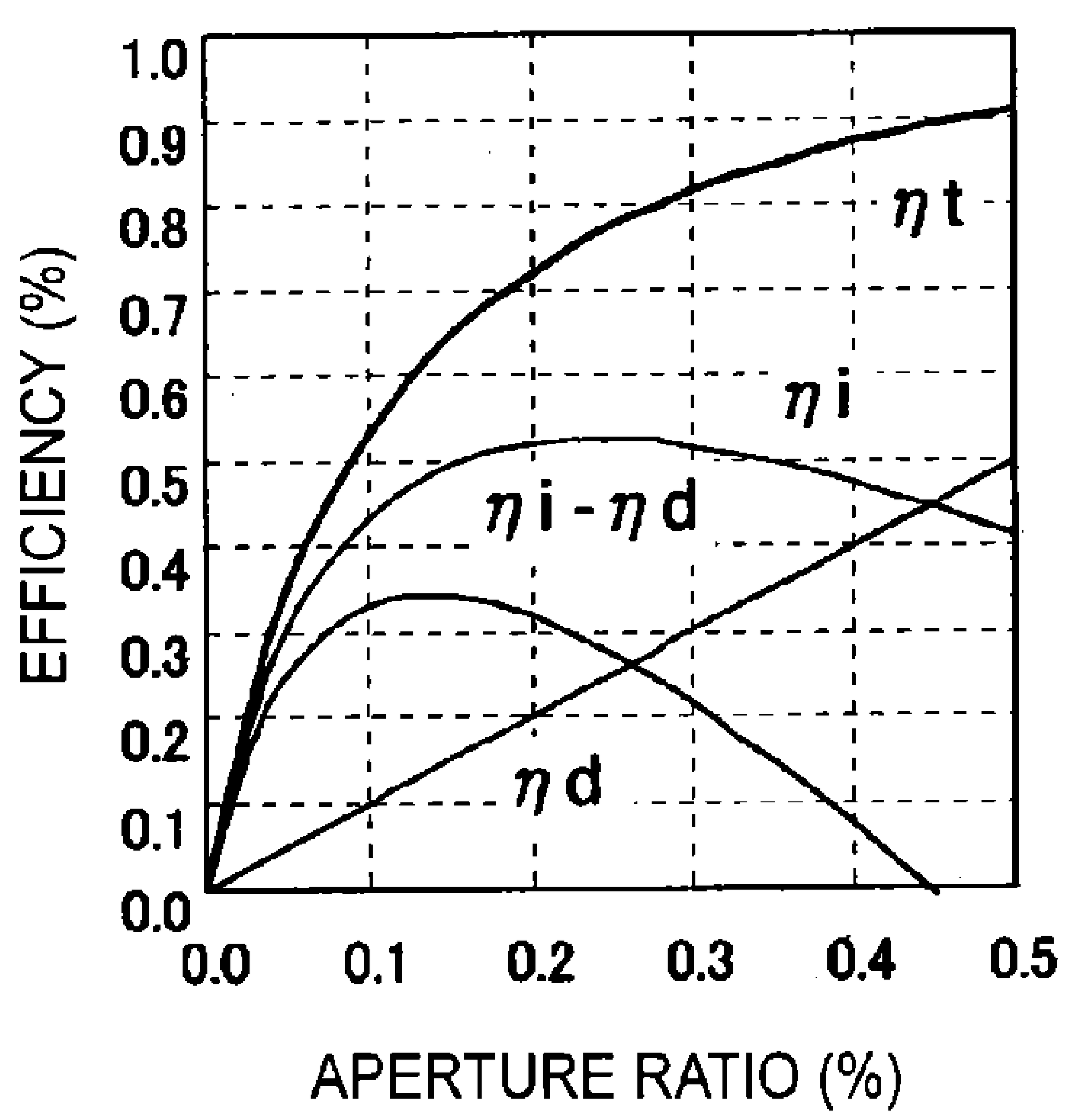


FIG. 6C

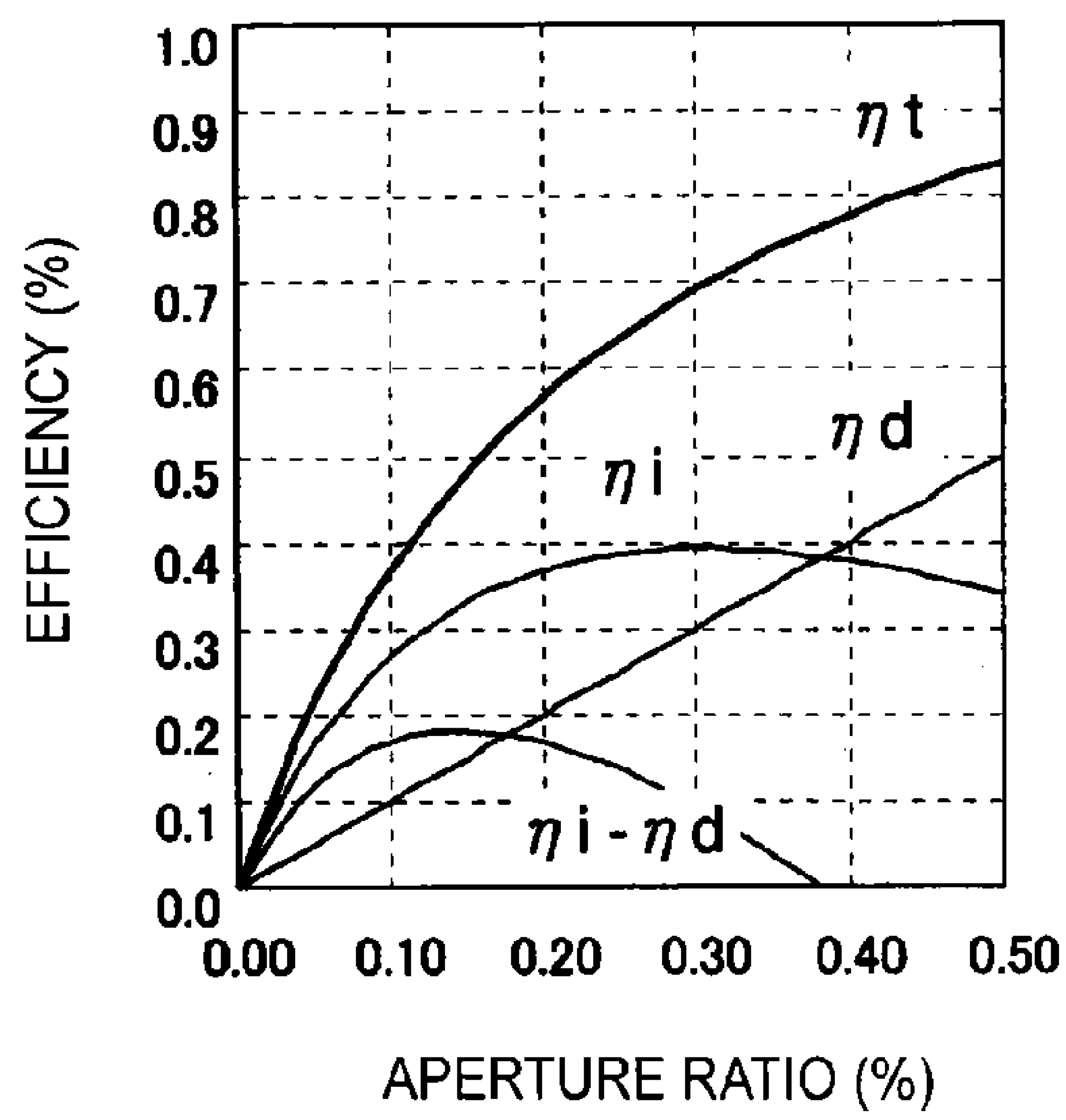


FIG. 6D

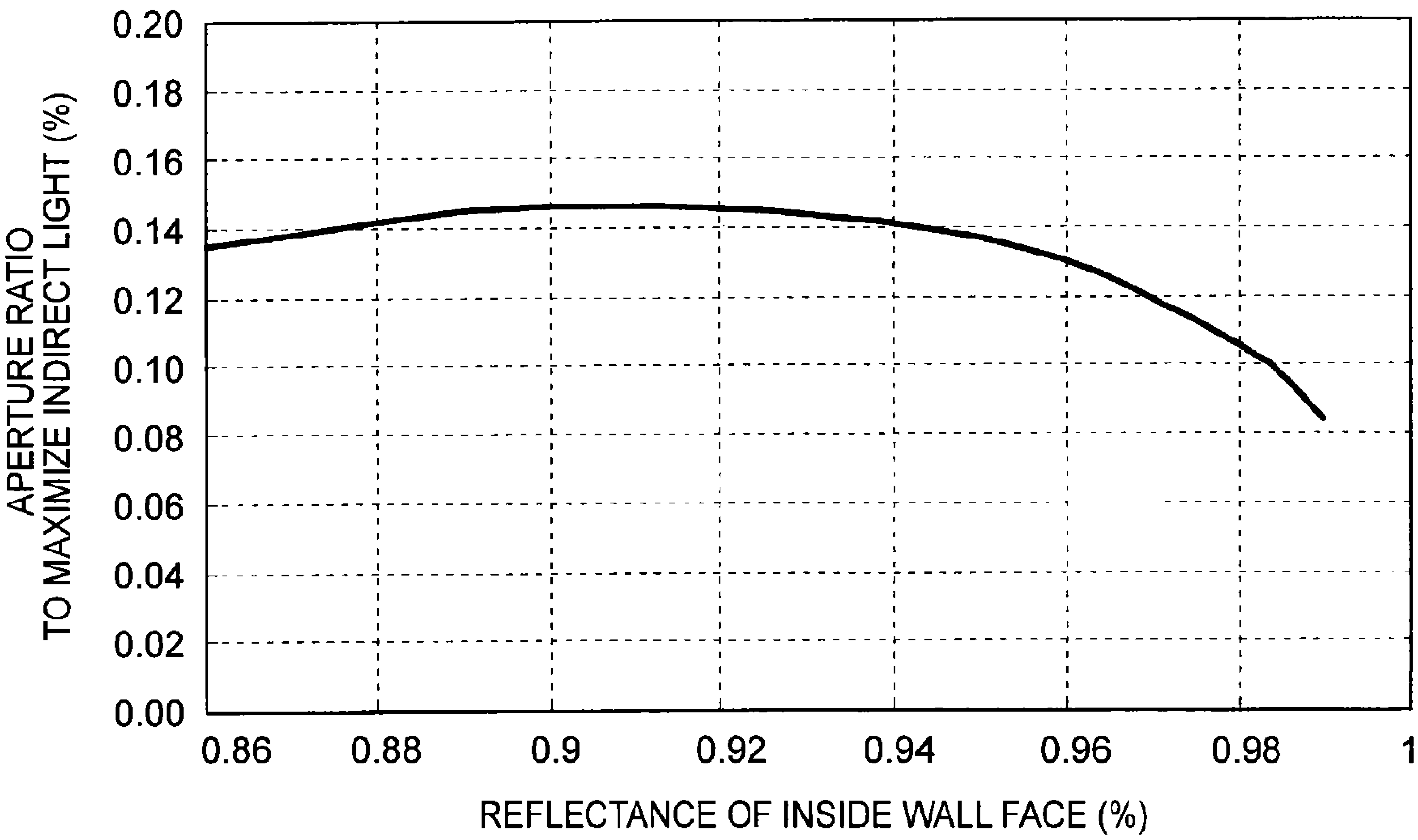

APERTURE RATIO
TO MAXIMIZE INDIRECT LIGHT (%)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.86
0.88
0.9
0.92
0.94
0.96
0.98
1
REFLECTANCE OF INSIDE WALL FACE (%)

FIG. 7

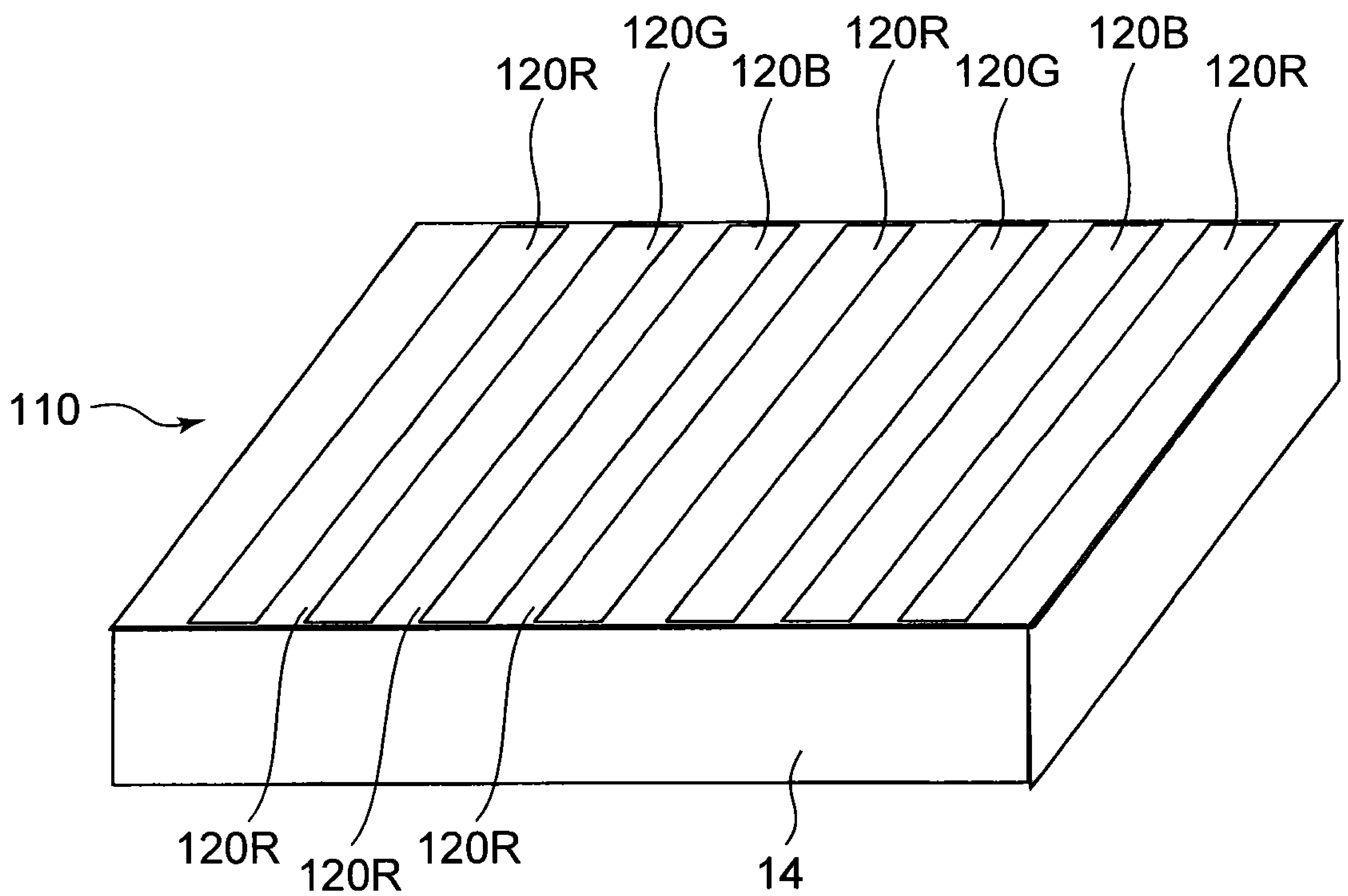


FIG. 8

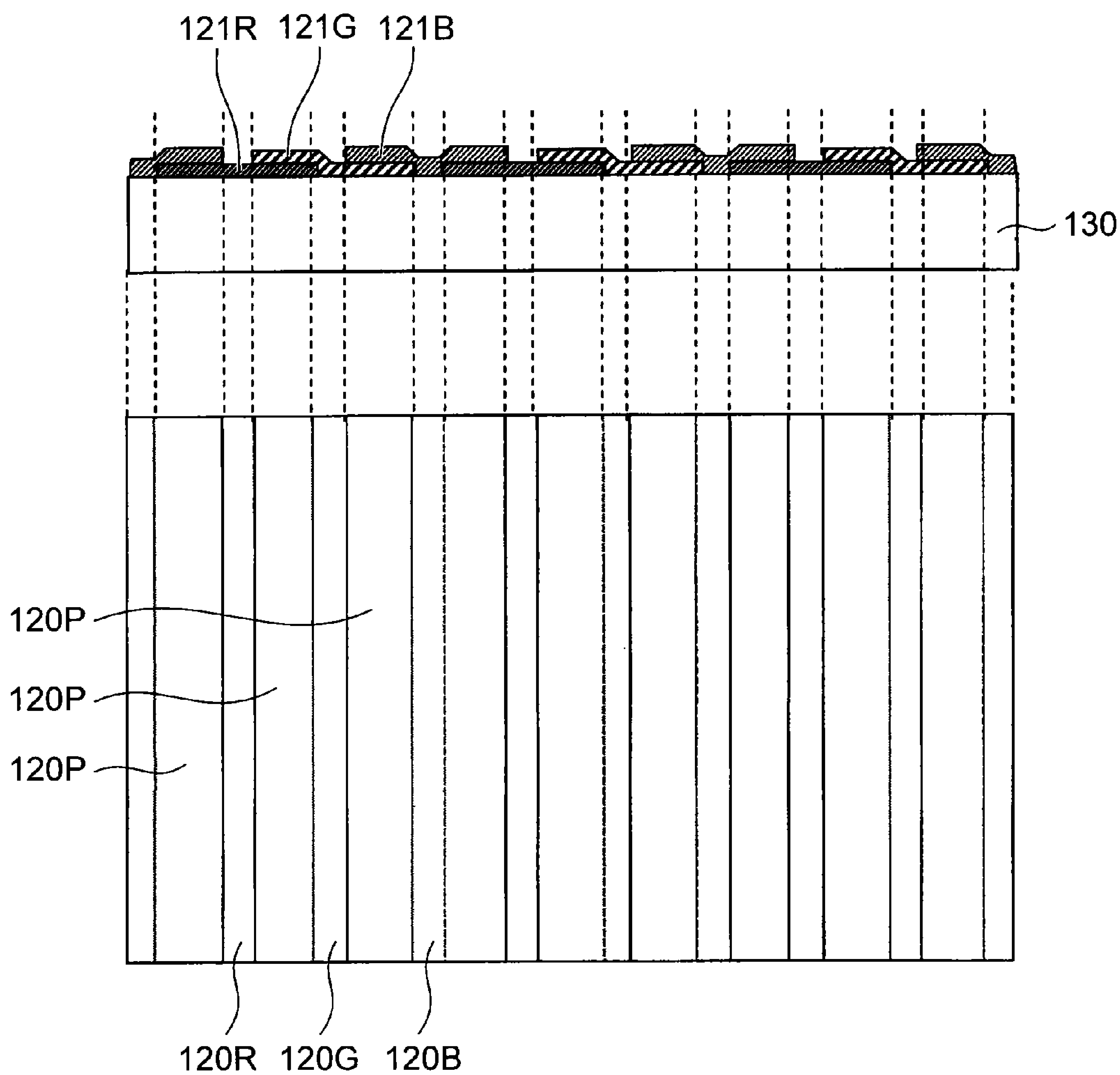


FIG. 9

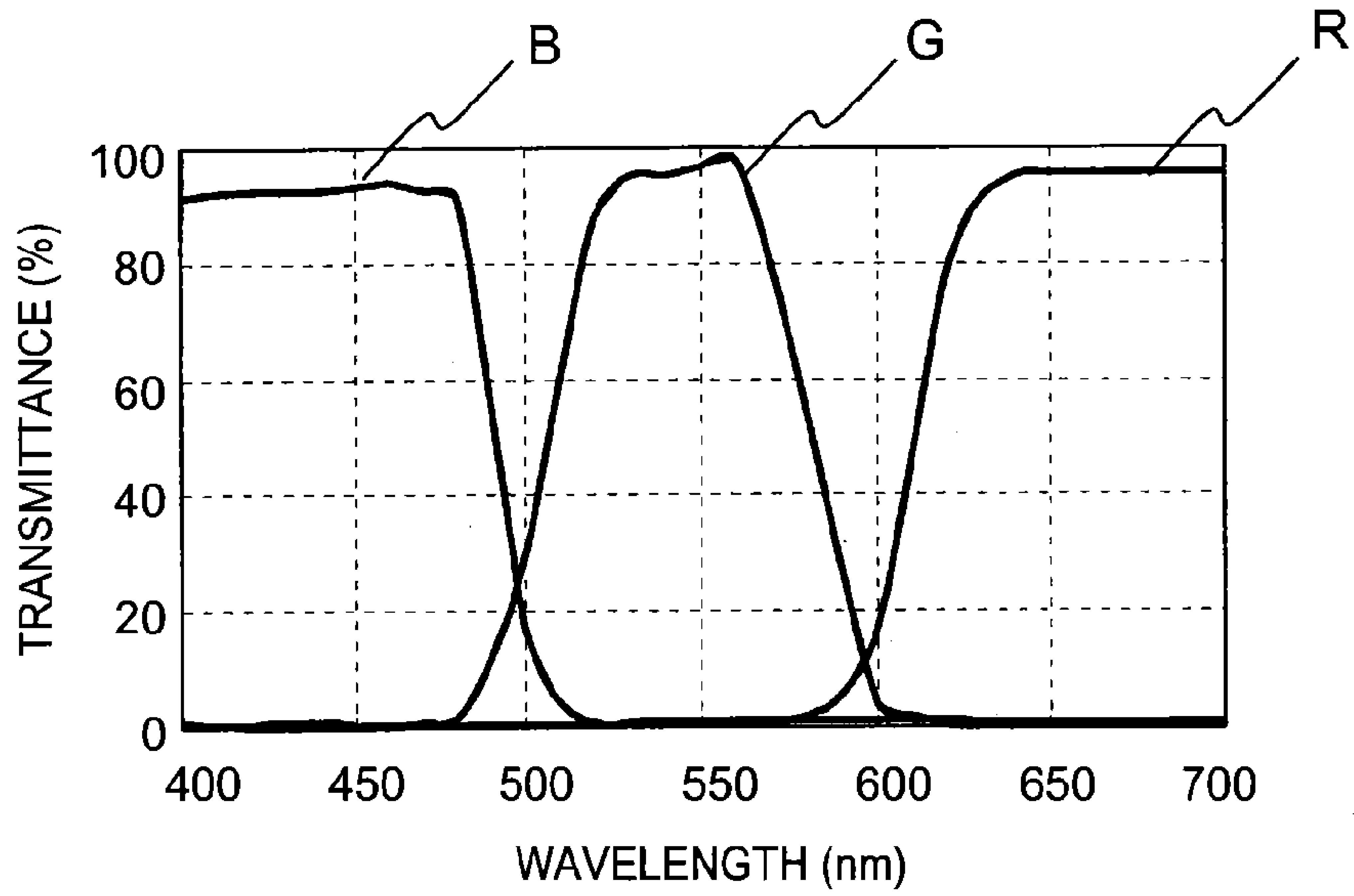


FIG. 10A

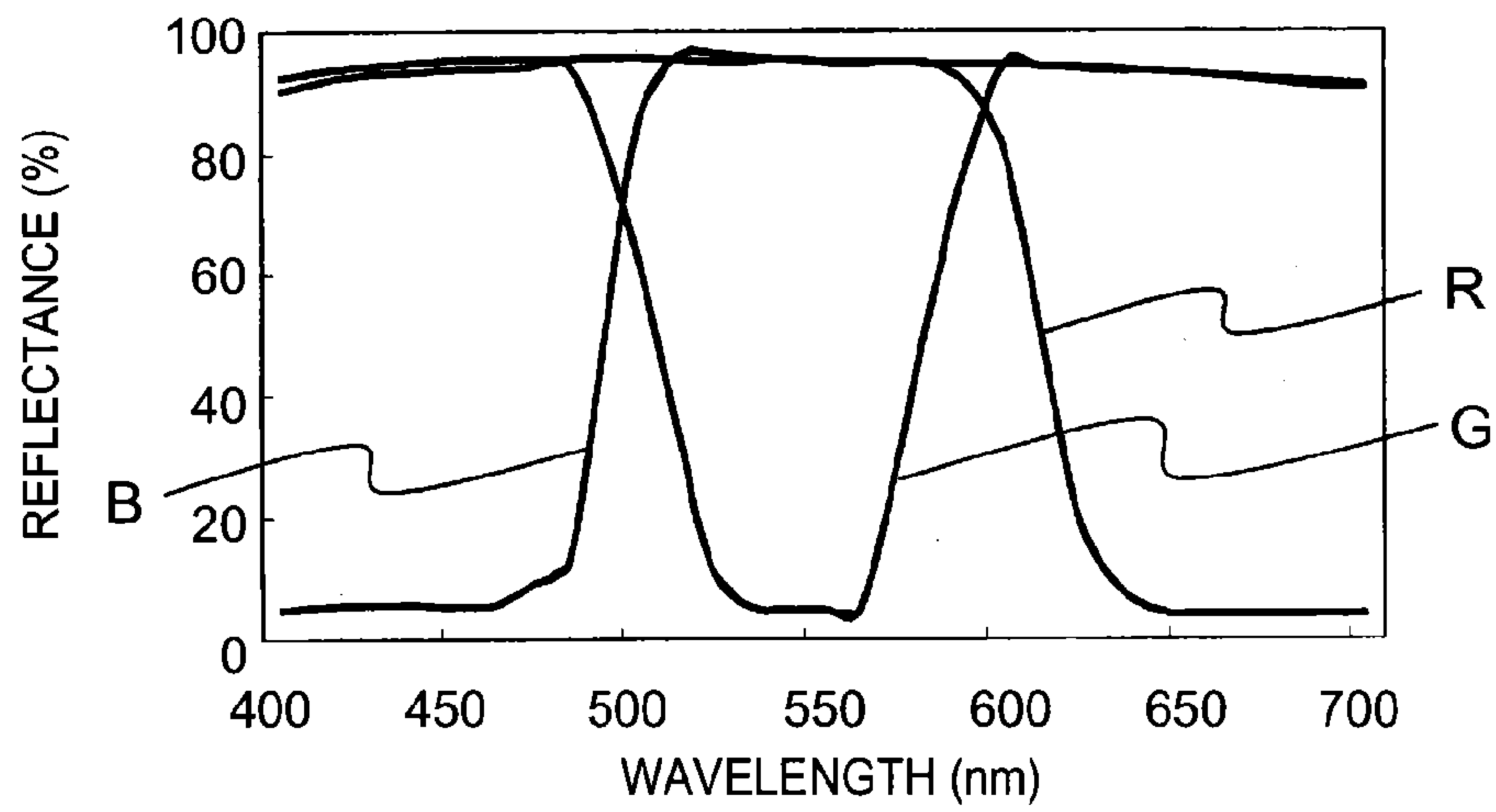


FIG. 10B

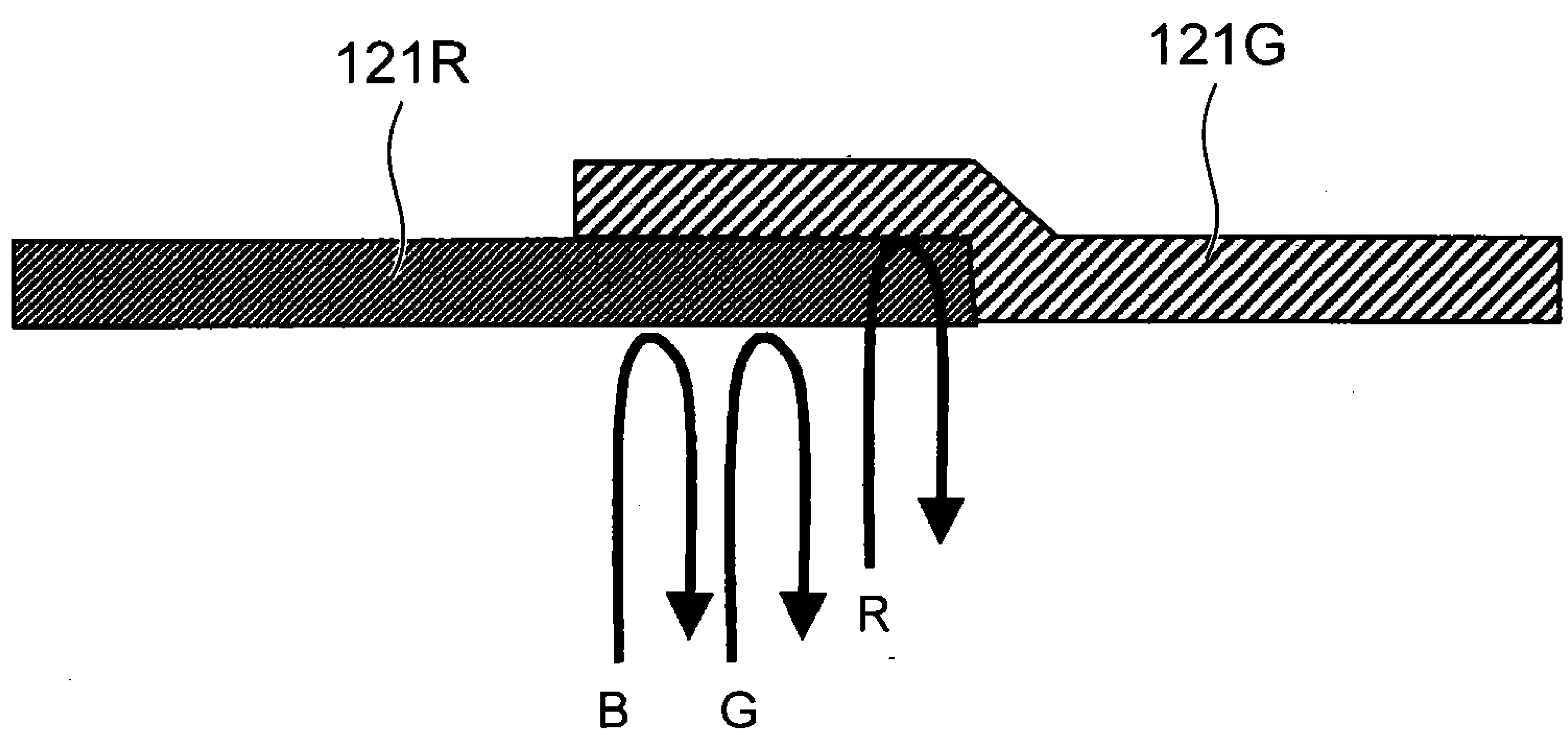


FIG. 11

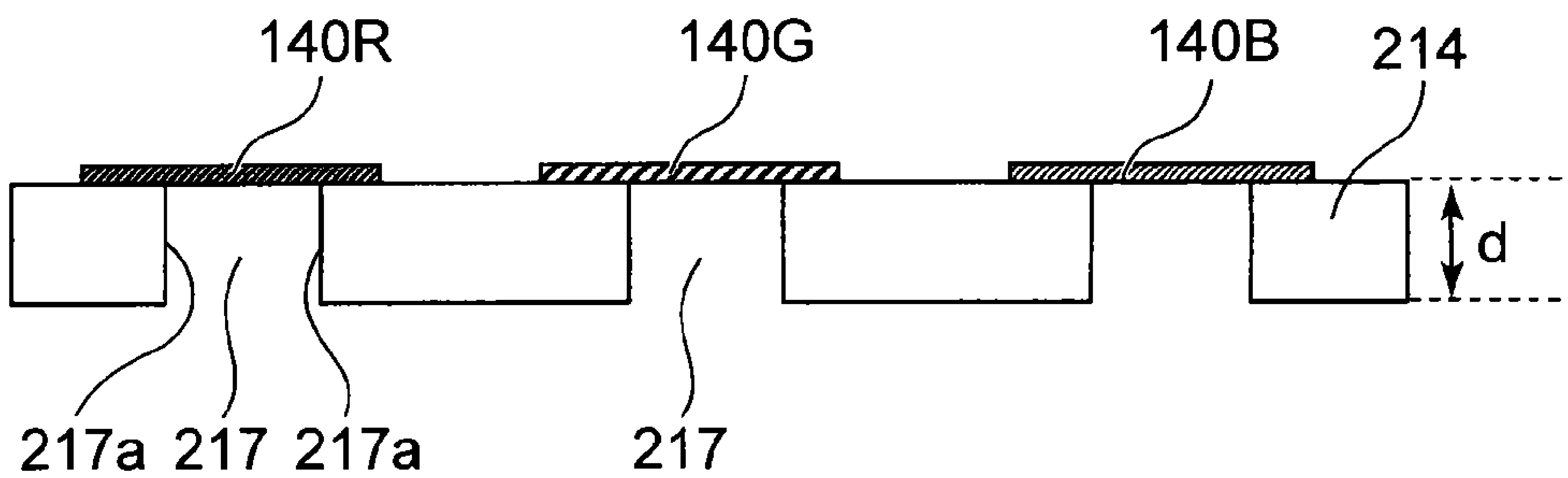


FIG. 12A

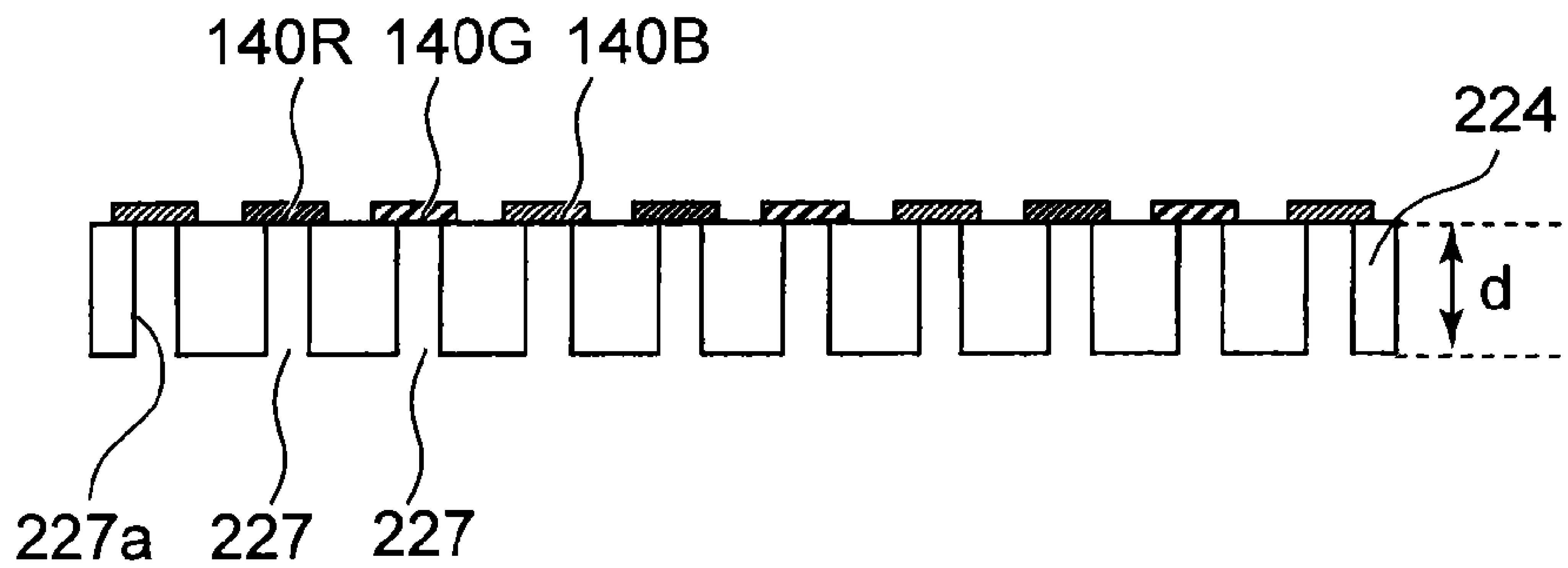


FIG. 12B

BACKLIGHT AND LIQUID CRYSTAL DISPLAY DEVICE

CROSS REFERENCE TO RELATED APPLICATION

This application is a division of and claims the benefit of priority under 35 U.S.C. §120 from U.S. Ser. No. 13/040,902 filed Mar. 4, 2011, and claims the benefit of priority under 35 U.S.C. §119 from Japanese Patent Application No. 2010-180590 filed Aug. 11, 2010, the entire contents of each of which are incorporated herein by reference.

FIELD

Embodiments basically relate to a backlight and a liquid crystal display device.

BACKGROUND

In recent years, a thin and light display device such as a liquid crystal display device has been widely used as a display for a personal computer and a display for a small-size television. In particular, when a liquid crystal display device is used for portable devices such as a portable computer and a portable television, it is required to reduce power consumption, because power is supplied by a battery.

A liquid crystal display device of transmissive type is provided with a backlight at a back face of a liquid crystal panel. Here, reducing power consumption of the backlight allows a reduction in power consumption of the liquid crystal display device.

BRIEF DESCRIPTION OF DRAWINGS

Aspects of this disclosure will become apparent upon reading the following detailed description and upon reference to accompanying drawings. The description and the associated drawings are provided to illustrate embodiments of the invention and not limited to the scope of the invention.

FIG. **1** is a sectional view showing a liquid crystal display device according to a first embodiment.

FIGS. **2**A to **2**C are perspective views showing a backlight in the first embodiment.

FIG. **3** is a view showing a cross-section of a liquid crystal panel in the first embodiment.

FIG. **4** is a view showing an example of a light path in the liquid crystal display device in the first embodiment.

FIG. **5** is a graph showing relations between an aperture ratio and an efficiency of light extraction in the first embodiment.

FIGS. **6**A to **6**D are graphs showing relations between the aperture ratio and the efficiency of light extraction in the first embodiment.

FIG. **7** is a graph showing a relation between a reflectance in an inside wall face of a case and the aperture ratio to maximize a rate of indirect light to the extracted light according to the first embodiment.

FIG. **8** is a perspective view showing a backlight according to a second embodiment.

FIG. **9** is an enlarged sectional view showing an upper face of the backlight in the second embodiment.

FIGS. **10**A and **10**B are graphs showing transmittances and reflectances of an interference filter in the second embodiment.

FIG. **11** is an enlarged sectional view showing an overlapped part between a red permeable membrane and a green permeable membrane of the interference filter according to the second embodiment.

FIGS. **12**A and **12**B are views showing sectioned upper faces of backlights of comparative examples.

DESCRIPTION

As will be described below, according to an embodiment, a backlight includes a case having two or more apertures in a main face thereof and a light source disposed inside the case. The total area of the apertures is not less than 8% and not more than 15% of the area of the main face.

First Embodiment

A liquid crystal display device having a backlight according to a first embodiment will be explained with reference to FIG. **1**. FIG. **1** is a view showing a cross-section of a display device capable of displaying a color image.

A liquid crystal display device **1** is provided with a liquid crystal panel **100** to display an image and the like, a lens array **18** having two or more lenses and facing the liquid crystal panel, and a backlight **10** facing the lens array **18**. The liquid crystal panel **100** is provided with an array substrate **102** having a number of pixel electrodes to be arranged in a matrix, a counter substrate **105** to face the array substrate **102**, and a liquid crystal layer **101** to be held between the array substrate **102** and the counter substrate **105**.

The lens array **18** focuses light from the backlight **10** onto the respective pixels of the liquid crystal panel **100**. The respective lenses have a section of a semicircular column shape and are aligned to protrude toward the side of the liquid crystal panel **100**.

The backlight **10** is provided with a hollow case **14** and a light source **15**, such as an LED, which is disposed on a lower wall face of the case **14** and inside the case **14**. Two or more apertures **17** are arranged at an upper wall face of the case **14** to face the lens array **18** and to correspond to the respective lenses thereof. The apertures **17** are covered with two or more interference filters **20** of light non-absorbing type (i.e., of reflection type).

FIGS. **2**A and **2**B are perspective views of backlights. As shown in FIGS. **2**A and **2**B, apertures **17** of the case **14** are arranged to be aligned in a row direction and in a column direction. FIG. **2**A shows circular apertures **17** and FIG. **2**B shows slit-shaped apertures **17**. Alternatively, the apertures **17** may be formed in the shape of a slit along the interference filters **20** as shown in FIG. **2**C.

The inside wall of the case **14** includes a material having a high reflectance. Metals such as stainless steel, resin or the like can be used for the material of the case **14** and the inside wall face thereof can be coated with aluminum, silver or the like. For example, aluminum or silver may be deposited on the inside wall face or a sheet on which aluminum or silver is deposited may be stuck to the inside wall face. The apertures **17** can be formed using a method such as injection molding, press working, laser machining, and etching.

The interference filter **20** includes a red interference filter **20**R, a green interference filter **20**G and a blue interference filter **20**B having selectivity of wavelength. The red interference filter **20**R allows red light to pass therethrough, and reflects green light and blue light. The green interference filter **20**G allows green light to pass therethrough, and reflects red light and blue light. The blue interference filter **20**B allows blue light to pass therethrough, and reflects red light and green light. Each interference filter **20** is formed of a dielectric multilayer including dielectric thin films having respective reflective indexes. Depending on a thickness of the dielectric multilayer, light of a certain wavelength passes through the dielectric multilayer while light of other wavelength is reflected.

For example, the dielectric multilayer is formed by means of alternately laminating a layer of a high reflective index material and a layer of a low reflective index material. Examples of the high reflective index material include TiO_2, Ta_2O_3, ZnO_2, ZnO_2, ZnS, ZrO_2, CeO_2, and Sb_2O_3. Examples of the low reflective index material include SiO_2, MgF_2, Na_3AlF_6.

One of the lenses of the lens array **18** is arranged for each row or column of the aligned apertures **17**.

FIG. **3** is an enlarged view showing a cross-section of the liquid crystal panel **100**. The array substrate **102** is provided with two or more pixel electrodes **104** and active elements **103** such as thin film transistors (TFT) on a main face thereof to hold the liquid crystal layer **101**. The counter substrate **105** is provided with a counter electrode **106** and color filters **107**R, **107**G, **107**B of absorption type on a main face thereof to hold the liquid crystal layer **101**. Here, although not shown in FIG. **3**, the actual liquid crystal panel **100** is provided with polarization plates on outer faces of the array substrate **102** and the counter substrate **105**.

The color filters **107**R, **107**G, and **107**B include a red color filter **107**R through which red light passes, a green color filter **107**G through which green light passes, and a blue color filter **107**B through which blue light passes. Each of the color filters **107**R, **107**G, and **107**B is arranged to face each pixel electrode **104**. Further, the red color filter **107**R, the green color filter **107**G, and the blue color filter **107**B are disposed above the red interference filter **20**R, the green interference filter **20**G, and the blue interference filter **20**B, respectively. A set of the color filters **107**R, **107**G, and **107**B of three colors constitutes one pixel. Here, the color filter **107** simply serves as an auxiliary of the interference filter **20**, and is not necessarily required.

FIG. **4** is a view showing an example of a path of light extracted from the apertures **17** in a cross-section of the liquid crystal display device.

A portion of light emitted from the light source **15** of the backlight **10** passes through each aperture **17** and the interference filter **20** of each color to come out of the backlight **10** (i.e., direct light). Another portion of light emitted from the light source **15** is repeatedly reflected by the interference filter **20** or the inside wall face of the case **14** to pass through each aperture **17** and the interference filter which allows light of the color to pass therethrough (i.e., multi-reflection light), thereby allowing the multi-reflection light to come out of the backlight **10**. The direct light and the multi-reflection light coming out of the backlight **10** pass through the red interference filter **20**R, for example, and are focused by the lens located just above the red interference filter **20**R. The focused beam of light forms an image in the vicinity of the liquid crystal layer **101**. The focal length is restricted so that the image does not exceed the range of the color filter **107**R in size. If the image formed by the lens is larger than the red color filter **107**R in size, the light spreads out toward the adjacent color filters **107**G and **107**B to be absorbed by the color filters **107**G and **107**B, thereby resulting in a loss. Thereafter, the image-forming light passes through the red color filter **107**R and the counter substrate **105** to come out of the display panel **100**.

Similarly, each light passing through the green interference filter **20**G and the blue interference filter **20**B is focused by the lens of the lens array **18** located just thereabove and forms an image in the vicinity of the liquid crystal layer **101**. The image-forming light passes through the green color filter **107**G or the blue color filter **107**B and then passes through the counter substrate **105** to come out of the display panel **100**.

FIG. **5** is a graph showing relations between an aperture ratio of the inside wall face of the case **14** and the light extraction efficiency η_t of the light extracted to the outside of the backlight **10** through the apertures **17**. In FIG. **5**, the horizontal axis denotes the aperture ratio and the vertical axis denotes the light extraction efficiency η_t. FIG. **5** shows the relations for reflectances of 85%, 90%, 95%, 98%, and 99% of the inside wall face of the case **14**. The aperture ratio denotes a value to be acquired by dividing the total area of the apertures **17** of the backlight **10** by the area of the upper face of the backlight **10**. Here, the area of the upper face of the backlight **10** includes the area of the apertures **17**. The light extraction efficiency η_t denotes a value to be acquired by dividing a total amount of the light extracted through the apertures **17** by a total amount of light passing through the area of the upper face (i.e., the face at which the apertures **17** are formed) of the backlight **10** in a state that the upper face thereof is removed. Here, both the total amount of the light extracted through the apertures **17** and the total amount of the light passing through the area of the upper face of the backlight **10** in the state that the upper face thereof is removed denote values without the interference filter **20**.

It is considered that the light extraction efficiency η_t increases with an increase in the reflectance of the inside wall of the case **14** and with an increase in the aperture ratio of the apertures **17**.

Details of the light extraction efficiency η_t have been studied to provide several findings as follows. FIGS. **6**A to **6**D show relations between the aperture ratio and each of the light extraction efficiency η_t, a light extraction efficiency η_d of the direct light, a light extraction efficiency η_i of the multi-reflection light, and a difference $\eta_i-\eta_d$. The difference $\eta_i-\eta_d$ is a difference between the light extraction efficiency of the multi-reflection light and the light extraction efficiency of the direct light.

The light extraction efficiency η_d of the direct light denotes a value acquired by dividing a total quantity of the direct light extracted through the apertures **17** by the total quantity of light exiting through the area of the upper face (i.e., the face at which the apertures **17** are formed) of the backlight **10** in the state that the upper face thereof is removed. The light extraction efficiency η_i of the multi-reflection light denotes a value acquired by dividing a total amount of the multi-reflection light extracted through the apertures **17** by the total amount of light permeating the area of the upper face of the backlight **10** in the state that the upper face thereof is removed. FIGS. **6**A to **6**D show reflectances of 99%, 98%, 95% and 90% of the inside wall face of the case **14**.

The light extraction efficiency η_d of the direct light is dependent on the aperture ratio to linearly increase. Further, the light extraction efficiency η_d of the direct light is not affected by the reflectance of the inside wall face of the case **14**, and remains approximately at the same value.

The light extraction efficiency η_i of the multi-reflection light reaches a maximum value at the aperture ratio of a certain fixed value and decreases when the aperture ratio becomes larger than the fixed value. Further, the light extraction efficiency of the multi-reflection light increases with an increase in the reflectance of the inside wall of the case **14**. Accordingly, it is considered that the total light extraction efficiency η_t increases as a whole with an increase in the reflectance of the inside wall face of the case **14** as a result of an increase in the light extraction efficiency η_i of the multi-reflection light.

Further, the light extraction efficiency η_t increases when the aperture ratio is large. This increase in the light extraction efficiency η_t includes a high light extraction efficiency η_i of the multi-reflection light and a low light extraction efficiency η_d of the direct light. When the light sources **15** are sparsely disposed on the inside wall face of the case **14**, an amount of the direct light passing through the apertures **17** located close to the light sources **15** is large and an amount of the direct light extracted through the aperture **17** located far from the light sources **15** is small. Meanwhile, the multi-reflection light comes out of every aperture **17** approximately by an equal amount regardless of an arrangement of the light sources **15**. Accordingly, when a rate of the direct light is larger than that of the multi-reflection light, brightness irregularity of the backlight **10** caused by the arrangement of the light sources **15** is apt to occur. Hence, when the aperture ratio is set so that the rate of the multi-reflection light in the light extracted through the apertures **17** becomes large, the brightness irregularity can be prevented.

The difference $\eta_i-\eta_d$ between the light extraction efficiencies of the multi-reflection light and the direct light increases with an increase in the aperture ratio in any reflectance of the inside wall face of the case **14**, and then decreases in due course after reaching the maximum value. The proportion of the multi-reflection light in the light extracted through the apertures **17** is the largest when the difference $\eta_i-\eta_d$ between the light extraction efficiencies of the multi-reflection light and the direct light reaches the maximum.

The value of the aperture ratio to maximize the difference $\eta_i-\eta_d$ between the light extraction efficiencies of the multi-reflection light and the direct light varies depending on the reflectance value of the inside wall face of the case **14**. FIG. **7** shows a relation between the reflectance of the inside wall face of the case **14** (i.e., the horizontal axis) and the value of the aperture ratio to maximize the difference $\eta_i-\eta_d$ between the light extraction efficiencies of the multi-reflection light and the direct light (i.e., the vertical axis).

It is shown that the aperture ratio to maximize the difference $\eta_i-\eta_d$ between the light extraction efficiencies of the multi-reflection light and the direct light stays within a range approximately between 8% and 15% if the reflectance of the inside wall face of the case **14** stays within a range between 86% and 99% inclusive. That is, restricting the aperture ratio of the backlight **10** within the range between 8% and 15% allows it to increase the rate of the multi-reflection light contained in the light from the backlight **10** and to decrease the rate of the direct light. Accordingly, the brightness irregularity can be reduced.

The backlight **10** without the interference filter **20** is used to acquire the appropriate aperture ratio range between 8% and 15%. That is, when nothing or no member having wavelength selectivity is disposed between the apertures and the crystal liquid panel, the aperture ratio is to be designed within the range between 8% and 15%. If the interference filters **20** of three colors are disposed at the apertures, only one third of the light from the light source **15** passes through one interference filter **20**, thereby designing the aperture ratio to triple the above appropriate range. That is, the aperture ratio of the backlight is designed to be within a range between 24% and 45%. Alternatively, the aperture ratio is designed to be within a range between 8×N % and 15×N % when interference filters of N colors are disposed. Here, N denotes a positive integer.

The above liquid crystal display device **1** has an effect to suppress brightness irregularity even without the interference filter **20** of the backlight **10**. However, as a result of the interference filters **20**, only the light of a color passing through the color filters **107**R, **107**G, and **107**B of the liquid crystal panel **100** passes through the interference filter **20**, while the light of a color which does not pass through the color filters **107**R, **107**G, and **107**B is returned into the case **14**. In this manner, it is possible to reduce a light loss of the light source **15** by the amount to be absorbed in the color filters **107**R, **107**G, and **107**B after coming out of the backlight **10**.

The present embodiment just provides an example and the scope of the present invention is not limited to the present embodiment.

Second Embodiment

A color filter of non-absorption type (i.e., an interference filter) reflects light of a color not passing through each color filter to recycle light, thereby enabling it to reduce power consumption of a backlight in comparison with a color filter of absorption type.

In the second embodiment, an interference filter for three colors disposed at the backlight will be explained. A main face having the interference filter of the backlight disposed is provided with an optically-transparent substrate and the interference filter without apertures. The interference filter is constituted with a part which allows light of a fixed wavelength to pass therethrough and a part which reflects light of every wavelength in a visible light range. When the part allowing light to pass therethrough is regarded as an aperture, the aperture ratio is designed to be within a range between 24% and 45%.

The rest other than the main face having the interference filter of the backlight disposed is the same as in the first embodiment. Detailed explanation will not be repeated.

FIG. **8** is a perspective view of a backlight **110**. FIG. **9** is a view showing a cross-section of a main face (i.e. an upper face) on the lens array side of the backlight **110**, and a top view of an interference filter **120** disposed on the backlight **110**. The upper face **116** includes a transparent glass substrate **130** and the interference filter **120** formed thereon.

The interference filter **120** is constituted with three types of membranes (i.e., a red permeable membrane **121**R, a green permeable membrane **121**G, and a blue permeable membrane **121**B) with dielectric films laminated. Following is an example to prepare an interference filter for respective colors by utilizing TiO_2 for a high reflective index layer and SiO_2 for a low reflective index layer. When the red permeable membrane **121**R having a ¼ wavelength membrane is regarded as a base unit, two or more sets of a ¼ wavelength membrane of a high reflective index layer and a ¼ wavelength membrane of a low reflective index layer which are alternately laminated are disposed on a ⅛ wavelength membrane of a low reflective index layer, and then a ⅛ wavelength membrane of a low reflective index layer is formed as a top layer.

Here, the interference filter having better characteristics, such as higher permeability for red light and higher impermeability for other color light, can be prepared as the number of layers increases. Specifically, the red permeable membrane **121**R can be prepared so that the thickness of the ¼ wavelength membrane of a TiO_2 layer is 50 nm and the thickness of the ¼ wavelength membrane of a SiO_2 layer is 84 nm. For example, two or more sets of a 72 nm-thick TiO_2 layer and a 123 nm-thick SiO_2 layer which are alternately laminated are disposed on a 61.5 nm-thick SiO_2 layer to prepare the green permeable membrane **121**G. After the 61.5 nm-thick SiO_2 layer is formed, a 21 nm-thick TiO_2 layer is formed thereon.

Then, two or more sets of a 72 nm-thick SiO_2 layer and a 72 nm-thick TiO_2 layer are laminated and a 21 nm-thick TiO_2 layer is formed thereon.

For example, two or more sets of a 104 nm-thick SiO_2 layer and a 60 nm-thick TiO_2 layer are laminated on a 30 nm-thick TiO_2 layer and then a 30 nm-thick TiO_2 layer is formed thereon in order to prepare the blue permeable membrane **121**B.

The red permeable membrane **121**R allows red light to pass therethrough and reflects other color light in the visible light range. The green permeable membrane **121**G allows green light to pass therethrough and reflects other color light in the visible light range. The blue permeable membrane **121**B allows blue light to pass therethrough and reflects other color light in the visible light range.

The red permeable membrane **121**R, the green permeable membrane **121**G and the blue permeable membrane **121**B are periodically aligned and adjacent membranes are partially overlapped. The overlapped part of the two membranes **121**R, **121**G, and **121**B reflects light of every wavelength in the visible light range (i.e., a reflection part **120**P).

Red light passes through a part (i.e., a red color part **120**R) of the red permeable membrane **121**R which is not overlapped with the other membranes **121**G and **121**B. Similarly, greed light passes through a part (i.e., a green color part **120**G) of the green permeable membrane **121**G which is not overlapped with the other membranes **121**R and **121**B. Blue light passes through a part (i.e., a blue color part **120**B) of the blue permeable membrane **121**B which does not overlap with the other membranes **121**R and **121**G.

That is, the red color part **120**R, the green color part **120**G and the blue color part **120**B are periodically aligned and the reflection parts **120**P are respectively formed therebetween. The red color part **120**R, the green color part **120**G and the blue color part **120**B are regarded as the apertures, because light passes therethrough. In the present embodiment, each area of the red color parts **120**R, the green color parts **120**G and the blue color parts **120**B is designed to be within a range from 8% to 15% of the area of the upper face of the backlight **110**. That is, the total area of the red color parts **120**R, the green color parts **120**G and the blue color parts **120**B which are regarded as the apertures is designed to be within a range from 24% to 45% of the area of the upper face of the backlight **110**.

The red permeable membrane **121**R and the green permeable membrane **121**G overlap with each other to form the reflection part **120**P located just between the red color part **120**R and the green color part **120**G. The reason why the overlapped part of two kinds of membranes reflects light of every color will be explained with reference to FIGS. **10**A and **10**B. FIG. **10**A is a graph showing an example of spectra of light passing through the red permeable membrane **121**R, the green permeable membrane **121**G and the blue permeable membrane **121**B, respectively. FIG. **10**B is a graph showing an example of spectra of light reflected by the red permeable membrane **121**R, the green permeable membrane **121**G and the blue permeable membrane **121**B, respectively.

For example, the red permeable membrane **121**R allows red light to pass therethrough and reflects light of other wavelength. Similarly, the green permeable membrane **121**G allows green light to pass therethrough and reflects light of other wavelength. The blue permeable membrane **121**B allows blue light to pass therethrough and reflects light of other wavelength.

FIG. **11** is a view showing a part at which a portion of the green permeable membrane **121**G overlaps with the red permeable membrane **121**R. When light is emitted from the light source located on the lower side of the red permeable membrane **121**R, blue light and green light are reflected by the red permeable membrane **121**R and only red light passes therethrough. However, the red light is reflected by the green permeable membrane **121**G and permeates through the red permeable membrane **121**R once again to return to the light source side. In this manner, light of every color is reflected by the reflection part **120**P.

As a method to prepare the interference filter **120** as shown in FIG. **9**, there has been a method to utilize a photolithography technology, for example. Specifically, membranes designed to allow permeation of red light and to reflect light of other colors are formed on a transparent glass substrate **130** at a prescribed pitch. Next, membranes designed to allow permeation of green light and to reflect light of other colors are formed at a prescribed pitch so as to partially overlap with the membrane allowing permeation of red light. At that time, there remain portions on the substrate **130**, which have neither the membrane allowing permeation of red light nor the membrane allowing permeation of green light formed. Subsequently, a membrane designed to allow permeation of blue light and to reflect light of other colors are formed so that the designed membrane covers portions which have not been covered with any membrane; a part of the designed membrane overlaps with the membrane allowing permeation of red light; and the other part of the designed membrane overlaps with the membrane allowing permeation of green light. In this manner, the interference filter **120** can be obtained.

In the above, the reflection part **120**P is exemplified, in which the green permeable membrane **121**G is overlapped onto the red permeable membrane **121**R. Similarly, every reflection part **120**P reflects light of every wavelength within the visible light range.

In the above, two kinds of the multilayer membranes are laminated to form the reflection part **120**P. Alternatively, a multilayer membrane to reflect light of every color may be newly formed. Here, laminating two kinds of the multilayer membranes can provide more reduced manufacturing steps than newly forming the membrane for the reflection part **120**P.

As described above, the interference filter **120** of the backlight **110** is designed so that parts allowing permeation of light are to be within the range from 24% to 45%. Accordingly, brightness irregularity can be prevented as well as in the first embodiment.

In addition, the light extraction efficiency of the backlight **110** using the interference filter **120** of the present embodiment could be higher than that of the backlight of which apertures are formed by making holes. A backlight having wide apertures will be compared with a backlight having narrow apertures with reference to FIGS. **12**A and **12**B. FIG. **12**A is a view showing a cross-section of the upper face of the backlight having wide apertures **217**. FIG. **12**B is a view showing a cross-section of the upper face of the backlight having narrow apertures **227**. Interference filters **140**R, **140**G, and **140**B for three colors are disposed above the apertures. The width of the apertures of the backlight **200** decreases with an increase in the resolution of a liquid crystal panel.

Light from the light source passes through the apertures **217** and **227** to come out of the backlight. Some light entering the apertures is reflected and diffused at the wall faces **217**_a_, **227**_a_ of the apertures to change the direction thereof.

When the apertures is narrower than the thicknesses d of the upper face **214** and **224** of the backlight, a rate of light (i.e., loss) being reflected and diffused at the wall face **227**_a_ of the apertures to change the direction thereof becomes high among the light entering the apertures **227**. Accordingly, there is a possibility that directionality of light is lost and the light extraction efficiency is decreased.

However, such a loss due to a decreased area of parts through which light passes does not occur in the embodiment employing the interference filter. Accordingly, the interference filter is applied to even a high-definition liquid crystal panel, thereby allowing it to prevent a decrease in the light extraction efficiency.

In the above, the inside wall face of the backlight is formed of aluminum or silver. However, it is also possible to dispose a dielectric multilayer on the inside wall face of the backlight. For example, a high reflective index dielectric material and a low reflective index dielectric material are alternately laminated as well as in the interference filter. Permeation of light is allowed in an infrared range and an ultraviolet range so that only light of wavelength within the visible light range is reflected. For example, when TiO_2 is used for the high reflective index layer and SiO_2 is used for the low reflective index layer, a 45 nm-thick SiO_2 layer is formed on the inside wall face of a case. Two or more sets of a 52.5 nm-thick TiO_2 layer and a 90 nm-thick SiO_2 layer are alternately laminated to be disposed on the 45 nm-thick SiO_2 layer, and are followed by formation of a 45 nm-thick SiO_2 layer thereon.

While a certain embodiment of the invention has been described, the embodiment has been presented by way of examples only, and is not intended to limit the scope of the inventions. Indeed, the novel elements and apparatuses described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods described herein may be made without departing from the spirit of the invention. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the invention.

What is claimed is:

1. A backlight comprising:
a case;
a light source disposed in the case; and
a filter of interference type disposed in a main face of the case,
wherein
the filter includes N kinds of membranes (N is a positive integer) which are periodically aligned;
the membranes are formed so that adjacent membranes are partially overlapped;
the membranes allow permeation of light within a fixed wavelength range and reflect light within a range of other wavelength in accordance with the kinds of the membranes; and
a total area of parts which do not overlap with the adjacent membrane of the membranes is not less than 8×N % and not more than 15×N % of an area of the main face on which the filter is disposed.

2. A liquid crystal display device comprising:
a liquid crystal panel including:
a pair of substrates; and
a liquid crystal layer held between the pair of substrates; and
a backlight including:
a case;
a light source disposed in the case; and
a filter of interference type disposed in a main face of the case facing the liquid crystal panel,
wherein
the filter includes N kinds of membranes which are periodically aligned (N is a positive integer);
the membranes are formed so that adjacent membranes partially overlap with each other;
the membranes allow permeation of light within a fixed wavelength range and reflect light within a range of other wavelength in accordance with the kinds of the membranes; and
a total area of parts which do not overlap with the adjacent membrane of the membranes is not less than 8×N % and not more than 15×N % of an area of the main face on which the filter is disposed.

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